

# FUNDAMENTALS OF LUBRICATION RELATING TO OPERATION AND MAINTENANCE OF TURBOMACHINERY

by

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## ABSTRACT

A properly designed, installed, operated, and maintained lubrication system is necessary for reliable machine performance. In this paper the principles involved in the operation and maintenance of a system are emphasized. The primary components of a system are described, including the lubricant itself. Sampling and testing techniques and their significance are discussed with special reference to the useful life of the lubricant change. Opinions are expressed regarding contaminants and their control, oil filter selection, flushing and cleaning techniques, and coupling lubrication.

## INTRODUCTION

The properly designed, installed, operated and maintained lubrication system is necessary for the reliable performance of turbomachinery. This paper will deal mainly with the principles of operating and maintaining the lubrication system. Figure 1 shows the topics that will be discussed in this paper. Many of the comments expressed will be opinions based on my experience with

1. Basic Oil System
2. Oil Selection
3. Sampling and Testing
4. Oil Contamination and Control
5. Filter Selection
6. Cleaning and Flushing
7. Coupling Lubrication

Figure 1.

lubrication systems for turbomachinery exposed to operating conditions relative to our plant, which is located on the Gulf Coast of Texas. Although some of our machine applications may differ from yours, it is my belief that all users of turbomachinery will have essentially the same basic concerns, especially those related to the lubrication systems. If you have questions, or if you disagree with my opinions, please make note of them and during the question and answer period I will attempt to clarify and further discuss your question.

## BASIC OIL SYSTEM

A special API task force has been working on a lube and seal oil standard for two or three years. It is my understanding that the proposed standard will be released late in 1972. This standard will be designated API 614 and will cover the minimum requirements for lubrication systems, oil type shaft sealing systems and control oil supply systems for "special purpose" applications such as compressors, gears, pumps and drivers. This is a much needed document that I sincerely hope will be released as planned.

I will not attempt to give a detailed review of this proposed standard but will make some comments concerning the major components of a typical oil system. Figure 2 lists some of these components. Most of the current turbomachinery is equipped with relatively well designed oil systems. However, many of the older systems were inadequately designed and frequently were the primary cause for machinery failure. These old, poorly designed systems should be revised to comply with API 614 as soon as possible.

The reservoir shown in Figure 3 should be separate from the equipment base plate. It should be sealed against the entrance of dirt and water. The bottom should be sloped to the low drain point and the return

1. The Reservoir
2. Oil Pumps
3. Oil Coolers
4. Oil Filters
5. Alarms and Shutdowns
6. Thermometers

Figure 2. Basic Oil System.

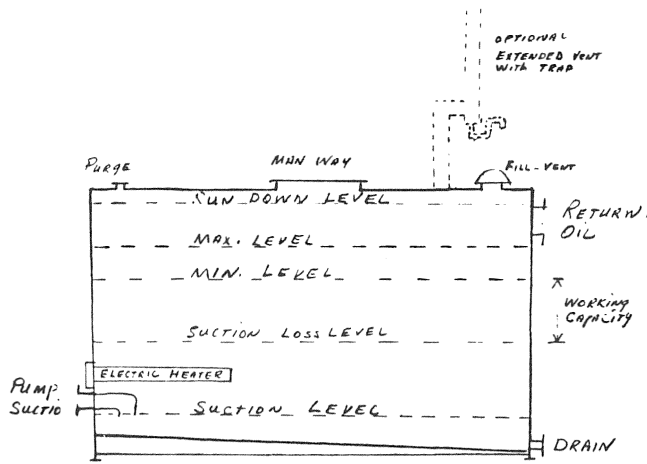


Figure 3. Reservoir.

oil lines should enter the reservoir away from the oil pump suction to avoid disturbance of the pump suction. The working capacity should be at least five minutes based on normal flow. Reservoir retention time should be 8 minutes, based on normal flow and total volume below minimum operating level. Heating the oil should also be provided. If thermostatically controlled electrical immersion heating is provided, the maximum watt density should be 15 watts per square inch. When steam heating is used, the heating element should be external to the reservoir.

The oil system should be equipped with a main oil pump, a standby pump and for critical machines, an emergency pump. Each pump must have its own driver and check valves must be installed on each pump discharge to prevent reverse flow through idle pumps. The pump capacity should be 15% greater than maximum system usage. The standby and emergency pumps shall be equipped with automatic controls to start the pumps on failure of the main oil pumps. This control system should have manual reset. If steam turbine and electric motors are to be used for the main and standby oil pumps, the steam turbine should drive the main pump and the electric motor should drive the standby pump. The emergency oil pump can be driven with an AC motor but from a power source that is different to the standby pump. DC electric motors can also be used when DC power is available. Process gas or air driven turbines and quick-start steam turbines are often used to drive the emergency pumps.

Twin oil coolers (Figure 4) should be provided and piped in parallel using a single multiport transflow valve to direct the flow of oil to the coolers. The water should be on the tube side and the oil on the shell side. The oil side pressure should be greater than the water side pressure. This is no assurance that water will not enter the system in the event of a tube leak but it does reduce the risk.

The oil system (Figure 4) should be equipped with full flow, twin oil filters located downstream from the oil coolers. Since the filters are located downstream from the oil coolers, only one multiport transflow valve

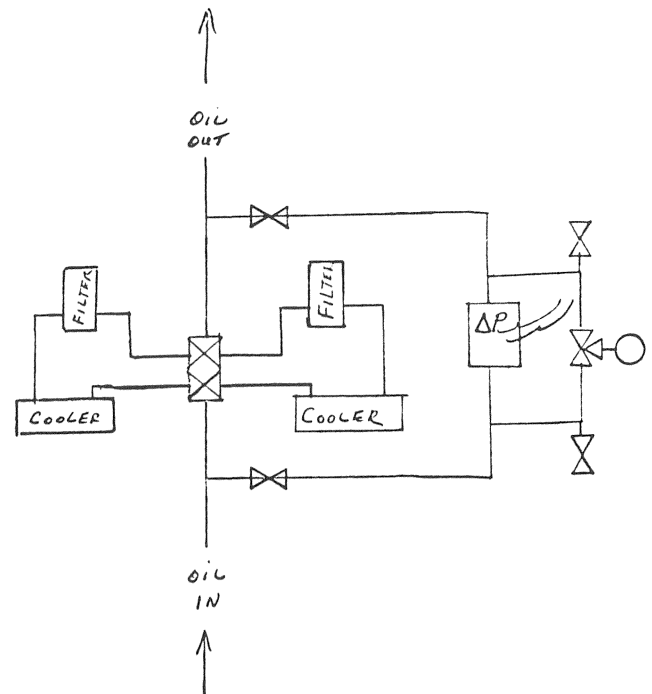


Figure 4. Cooler-Filter Arrangement.

is required to direct the oil flow to the cooler-filter combinations. **DO NOT** pipe the filters and coolers with separate inlet and outlet block valves—this could cause loss of oil flow from the possible human error of blocking the flow during a filter switching operation.

The minimum alarms and trips (Figure 5) recommended for each major driver and driven machine should be a low oil pressure alarm, a low oil pressure trip (at some point lower than the alarm point), low oil level alarm (reservoir), high oil filter differential pressure alarm and high bearing metal temperature alarm.

Each pressure and temperature sensing switch should be in separate housings. The switch type should be single-pole, double-throw, furnished as "open" (de-energized) to alarm and "close" (energize) to trip. The

	Alarm	Trip
Low Oil Pressure	X	X
Low Oil Level	X	
High Oil Filter	X	
High Thrust Bearing Metal Temperature	X	
High Thrust Bearing Oil Temperature	X	

Figure 5.

1. Right Viscosity
2. Rust Inhibitor
3. Oxidation Inhibitor
4. Non-Sludging
5. Resist Foaming
6. Good Demulsibility

*Figure 6. Turbomachine Oil Characteristics.*

pressure switches for alarms should be installed with a "T"-connection pressure gage and bleeder valve for testing the alarm.

Thermometers should be mounted in the oil piping to measure the temperature of the oil flow into and out of the coolers, and the outlet of each radial and thrust bearing.

Pressure gages should be provided at the discharge of the pumps, the bearing header, the control oil line and the seal oil system.

Each atmospheric oil drain line should be equipped with steel nonrestrictive bull's-eye type flow indicators positioned for viewing through the side.

#### LUBRICANT REQUIREMENTS

Oil suitable for turbomachinery (Figure 6) should be of the correct viscosity and formulated with the required chemical additives to prevent rusting, resist oxidation and sludging, be noncorrosive to machine parts, resist foaming and separate rapidly from water.

The oil has several functions (Figure 7) in addition to simple lubrication. It must cool bearings and gears, prevent excessive metal-to-metal contact during starts, transmit pressure in control systems, and carry away foreign materials, reduce corrosion, and resist degradation.

The selection of the correct lubricant (Figure 8) must begin with the manufacturers. Refer to the operator's instruction manual for the type oil required and the recommended viscosity range. If you have not had experience with this particular equipment, the lubricant

1. Lubricate Bearings
2. Transmit Governor Impulses
3. Cooling Medium
4. Prevents Rust
5. Prevents Sludging

*Figure 7. Turbomachine Oil Functions.*

1. Manufacturers' Specification
2. Oil Supplier Recommendation
3. Past Experience

*Figure 8. Oil Selection.*

suppliers should be consulted for their recommended lubricant to meet the manufacturer's requirements. Usually past experience with the same type or similar turbomachinery in the same or similar service is the best guide.

The local environmental conditions should be seriously considered. Will the oil be exposed to acid type gas? Is the reservoir located outside in the elements or is it under cover? Will the oil be exposed to water from atmospheric condensation or steam leaks? As a general rule most turbomachines are lubricated with premium quality turbine grade oil. However, under certain environmental conditions, it may be advantageous to consider another type oil. For example, if a machine is subject to the exposure of low concentration of chlorine or anhydrous hydrochloric acid gases, it is entirely possible to select another type oil that will out-perform the premium turbine oil. Good results have been recorded using oil containing alkaline type additives. Certain automotive or diesel engine oils contain the optimum amount and type of alkaline additives to protect the base oil from reaction with chlorine and HCl. Before an oil is used in this service, it should be evaluated in the laboratory. This is done by exposing the oil to a low concentration of chlorine for a given time. The exposed samples should be tested for viscosity change, pH, neutralization number and percent sludge. The lubricant most suitable for this service should yield the least change in viscosity, less than 20% with less than 0.2% sludge indicated by the precipitation test.

#### OIL SAMPLING AND TESTING

Oils from turbomachinery should be tested periodically (Figure 9) to determine their suitability for con-

1. Viscosity
2. pH and Neutral Number
3. Precipitation Number
4. Specification Analysis — Wear Metals
5. Atomic Absorption — Wear Metals
6. Infrared
7. X-ray Defraction

*Figure 9. Used Oil Analysis.*

## I. Extraneous Matter

### A. Atmospheric Dirt

### B. Metal Particles

### C. Water

## II. Process Gas

*Figure 10. Oil Contamination.*

tinued use. However, visual inspection of the oil can be useful in detecting contaminated oil when the appearance and odor is changed by the contaminant.

A sample of the oil should be withdrawn from the system and several of its characteristics measured in the laboratory. The usual tests conducted to determine the condition of the used oil include: (1) viscosity, (2) pH and neutralization number, and (3) precipitation. There are, however, additional tests that can be conducted for a more detailed evaluation of the used oil. Those tests are: (1) spectrographic analysis, (2) atomic absorption, (3) infrared analysis, (4) X-ray and (5) interfacial tension. The test results should be reviewed and compared with the supplier's specifications of the new oil. Depending upon the nature or degree of departure from new oil, the laboratory either will approve the oil for continued use or advise the machine owner of any action that should be taken in the way of reconditioning or replacement of the oil. Good records should be kept for all samples tested.

## OIL CONTAMINATION

The contamination of circulating oil (Figure 10) in turbomachinery is a continuing problem in almost all installations. The difference is degree of contamination, influenced to a large extent by the environmental conditions to which the machinery is exposed and the mechanical condition of the oil, steam and process gas seals.

The greatest source of contamination is from extraneous matter. Atmospheric dirt is always a serious threat to the turbomachine. It can gain entrance into the oil system through vents, breathers and seals. The effects of this type contamination is obvious—primarily equipment wear. However, the plugging of oil lines and ports and reduced oxidation stability of the oil are other serious effects.

Metal particles from wear and rust particles from reservoir and oil piping corrosion can lead to premature equipment failure and oil deterioration. It is important to provide suitable filtering equipment for the removal of these particles from the system.

Water contamination is a constant threat. The sources of water are many—atmospheric condensation, steam leaks, oil coolers and reservoir leaks. Rusting of machine parts and the effects of rust particles in the oil system is the major product of water in oil. In addition,

it forms an emulsion and combined with other impurities, such as wear metal and rust particles, acts as catalysts promoting oil oxidation.

Contamination from process gas can be a serious problem, particularly during startup. Every necessary effort must be exercised to prevent this type contamination and provide methods of detection if it should occur.

Most hydrocarbon gases are more soluble in cold oil than in hot oil and may lower the viscosity to a dangerous level. The problem of thrust bearing failures during startup due to low viscosity oil can be eliminated by equipping the reservoir with oil heaters to raise the oil to the normal operating temperature before starting the machine.

Equipment in HCl and chlorine service must be protected against the exposure of these acid gases to the oil. Obviously, the first line of defense is to eliminate seal failures. However, as a secondary protection these machines could be lubricated with an alkaline oil. The alkaline additives would be available to react with the low concentrations of the acid gases, thus eliminating addition of these acids to the oil molecule.

Further protection can be provided by the use of an alkaline oil-mist purge on the bearing housings and the reservoirs. The alkaline mist can be admitted at the rate of .25 CFM on each bearing and .5 CFM on the reservoir. With the vapor spaces filled with the alkaline oil-mist, any ingress of an acid gas would be neutralized before contact with the circulating oil.

## CONTAMINANT REMOVAL

The removal of contaminants (Figure 11) must be done continuously with equipment suitable for the type contaminants in the oil. Keeping the oil clean is an important function to approaching trouble-free operation. We should therefore select the very best method and equipment required to maintain clean oil systems.

### Insoluble Particles

1. Depth Filters
2. Surface Filters
3. Element Selection

### Water

1. Prevention Best Cure
2. Removal Methods
  - A. Centrifuges
  - B. Coalescer Separators

*Figure 11. Contaminant Removal.*

Insoluble particles can be successfully removed from the circulating oil with full flow filters. Two general types are usually selected for the removal of this type contaminant. They are surface filters and depth filters. Both of these type filters are effective for the removal of particulate matter.

The depth type filter elements are generally used when the oil is free from water and when particle sizes to be removed are in the 5-micron and larger range. Generally, the depth type element is water sensitive and when oil is contaminated with moisture, this type element will absorb the water and produce a rapid increase in differential pressure across the filter. High differential pressures are also developed when the filter element density is great enough to remove particles smaller than 5 microns. The desired maximum differential pressure across a filter with clean elements is 2 psig, at the normal operating temperature. However, many filters were designed for 5 psig with 10-micron elements. These filters when equipped with 5-micron type elements may yield differential pressures as high as 8-10 psig.

Surface filters, if manufactured from the correct material, will not be affected by water in the oil. Water-resistant pleated paper elements have much larger surface areas than the depth type element and yield a much lower differential pressure when used as replacement elements in filters originally equipped with depth type elements. Pleated paper elements are available that will remove particle sizes down to nominal  $\frac{1}{2}$  micron.

#### ELEMENT SELECTION

The filter elements should be 5 micron and must be water resistant, have high flow rate capability with low pressure drop, possess high dirt retention capacity and be rupture resistant. The clean pressure drop should not exceed 5 psig at 100°F. We prefer to size the filters large enough to yield at 2 psig differential pressure at 100°F. The elements must have a minimum collapse differential of 50 psig. Pleated paper elements are preferred provided they meet these requirements. Usually the pleated paper element will yield the 2 psig clean drop when used in a filter that was sized to use depth type elements. This is due to the larger surface area of the pleated element, over twice the area of a conventional stacked disc type or other depth type elements. We are successfully replacing 5-micron pleated paper elements in two 80 gpm consoles with  $\frac{1}{2}$ -micron pleated paper elements. The initial differential pressure with the 5-micron elements was 2 psig and when  $\frac{1}{2}$ -micron elements were installed the differential pressure only increased to 5 psig.

Some of our early designed oil systems were equipped with bypass relief valves set to open at approximately 20 psig differential, a safeguard against oil flow loss due to dirty elements. The bypass valves are not recommended and have been removed. A better protection against the loss of oil flow is a differential pressure switch set to alarm when the pressure drop reaches a predetermined point. In addition to the differential pressure switch, a two-way, three-port valve with a pressure gage is piped in parallel with the differential pressure

switch for accurate indication of inlet and outlet oil filter pressure. When a single transflow valve is used with a cooler-filter installation, the differential pressure switch and pressure gage assembly should span the cooler-filter system.

Water contamination in the oil system can be a serious detriment to the turbomachinery and every reasonable effort should be made to, first, prevent its entrance into the system and second, provide suitable removal equipment if water cannot be effectively kept out. I am a strong believer that "*prevention*" is the best cure. Experience indicates the designers and the equipment operators can be more effective in keeping water out of the system. Since the main sources are from atmospheric condensation, steam leaks and faulty oil coolers, it is obvious that preventive measures should be taken in these areas.

Condensation will occur in the atmospheric vented oil system whenever the temperature in the vapor space areas drops below the dew point. This can be in the return oil piping as well as the reservoir. Consoles installed in unprotected locations are more vulnerable to climatic changes than those installed inside buildings. The outside locations will be adversely affected by temperature cycles between daytime and night operations—also, by showers and sudden temperature drops due to other weather changes, especially in the fall and winter seasons. We have been very successful in "drying up" oil systems by making a few simple alterations. The first step that should be taken is to check the reservoir vent. The vent should be located in the very top of the reservoir. It should be free of baffles that would collect and return condensate to the reservoir and the length should be kept as short as possible to provide minimum surface areas on which condensate could form. It is necessary to run the vent up and away from the reservoir, a water trap should be provided as close to the reservoir as possible to remove any condensate formed in the vent stack. The next step is to provide and maintain an inert gas or dry air purge on the reservoir, only two to five CFH is required. The reservoir purge system will not substitute for the elimination of other water sources.

Steam and condensate leaks are the most difficult sources of water to prevent; however, it can be done and every effort should be made to eliminate those sources. Obviously, the first means of prevention is to maintain the steam packing in perfect condition. Experience has shown that eventually the steam packings will leak and steam condensate will enter the system through the bearing seals. We have also been successful in "drying up" this type wet oil system. The procedure we used was to purge the bearing labyrinths with inert gas or dry air. One method is to drill a  $\frac{1}{8}$ " hole through the bearing cap and intersect the labyrinth. A  $\frac{1}{4}$ " copper tubing is connected to the hole in the bearing cap and to a rotometer. The labyrinth is then purged with 15 CFH dry air or inert gas.

Another method was to install an external labyrinth with purge provisions on the bearing housings of a machine that had the necessary space to accommodate the external seal.

Both of these methods have worked very well and we are therefore encouraging our turbomachinery operators to make these provisions available for use if or when the steam packings begin to leak.

The methods of removing free water from oil systems is usually done with either centrifuges or coalescer separators. We are successfully using both of these methods in our various operating units. Although we are using both methods, I prefer the coalescer separator. Experience has shown the centrifuge is the most costly method, both from capital outlay and operating cost. The centrifuges we use are the conventional disc type with manual cleaning. The discs must be cleaned at least once each week with one hour required per cleaning. The coalescer separators usually require much less attention. Some separators only require element changes once a year while others may require changes at 6 months or 3 months and in some instances, once a month. The frequency appears to be related to the amount of water in the oil system. The coalescer element changes have been reduced in many instances by the use of a pre-filter in the system. The pre-filter element we are using has a nominal  $\frac{1}{2}$ -micron retention rating. This element removes the particulates, usually rust, that would restrict the 2-micron coalescer element. The time required to change both the pre-filter element and coalescer separator elements is less than one hour.

### OIL SYSTEM CLEANUP

Serious mechanical damage to turbomachinery can result from operating with dirty oil systems (Figure 12). It is essential that the oil system be thoroughly cleaned up prior to the initial startup of a new machine and after each overhaul of existing machines.

Preliminary steps for the initial startup and after the overhaul are similar except for the reservoir and oil requirements on the machine after an overhaul. For the overhauled machine the oil would be drained and tested for condition. Retain the oil unless the lab tests indicate otherwise. It may be grossly contaminated with wear metal, water, process product or otherwise degraded and unfit for future use. If this is the case, the oil should be discarded, otherwise, the good oil would be stored in a suitable auxiliary holding tank.

Inspect the reservoir interior for rust and other deposits. Remove any rust with scrapers and wire brushes and wash down the interior with a detergent solution and flush with clean water. Dry the interior by blowing the surfaces with dry air and use a vacuum cleaner for liquids to remove trapped water.

1. Initial Startup
2. Overhauled Machinery
3. Preliminary Preparations
4. Flushing Procedure

*Figure 12. Oil System Cleanup.*

Install new 5-micron pleated paper elements in the filters. Connect steam piping to the water side of the oil coolers for heating the oil during the flush. Remove orifice and install jumpers at the bearings, coupling, controls, governor, and other critical parts to prevent damage from debris during the flush. Make provisions for 40-mesh telltale screens at each jumper. The conical shaped screen is preferred but a flat screen is acceptable if the conical screen is not available. Adjust all control valves in the full open position to allow maximum flushing flow. The effectiveness of the flush is dependent to a large extent on high flow velocities through the system to carry the debris into the reservoir and filters. It may be necessary to sectionalize the system to obtain maximum velocities by alternately blocking off branch lines during the flush.

Fill the reservoir with new or clean used oil. Begin the flush without telltale screens by running the pump or pumps to provide the highest possible flow rate. Heat the oil to 160°F with steam on the oil cooler. Cycle the temperature between 110°F and 160°F to thermally exercise the pipe. Tap the piping to dislodge debris, especially along the horizontal sections. Flush through one complete temperature cycle, then shut down and install the telltale screens and flush for an additional 30 minutes. Remove screens and check for amount and type debris. Repeat the preceding procedure until the screens are clean after two consecutive inspections. Observe the pressure drop across the filters during the flushing operation. Do not allow the pressure drop to exceed 20 psig. When the system is considered clean, empty the oil reservoir and clean out all debris by washing with a detergent solution followed by a fresh water rinse. Dry interior by blowing with dry air and vacuum free water. Replace filter elements. Remove jumpers and replace orifices. Return controls to their normal settings. Refill the oil reservoir with the same oil used in the flush if lab tests indicate it is satisfactory; otherwise, refill with new oil.

This procedure will allow the fastest possible cleanup of the oil system, mainly due to the high flow velocities obtained during the flush. The objective is to carry the debris into the reservoir and filters and the turbulence from the high flows along with the thermal and mechanical exercising of the piping are the main factors necessary for a fast and effective system cleanup.

### GEAR TYPE LUBRICATED COUPLING

The flexible coupling (Figure 13) is one of the most critical components in the turbomachine and requires special consideration from the standpoint of selection, installation, operation and lubrication.

Unless the properly designed coupling was selected by the machine designer, many operating problems will be experienced, some of which may be mistaken as lubrication problems. Successful operation can be realized when the properly designed coupling has been correctly installed with the most suitable method of lubrication applied. For the benefit of this discussion, let us assume that properly designed gear type coupling will be applied and it will be correctly installed on the machinery.

## **Coupling Types**

1. Grease Packed
2. Oil Filled
3. Continuous Oil Flow

### **Grease Packed and Oil Filled**

1. Advantages and Disadvantages
2. Lubricant Selection

### **Continuous Oil Flow**

1. Requisites for Good Performance
2. Advantages and Disadvantages
3. Oil Filtration

*Figure 13. Gear Type Lubricated Couplings.*

The most commonly applied methods of lubricating gear type couplings are (1) grease-packed, (2) oil-filled or (3) continuous oil flow. Each of these three methods have certain advantages and disadvantages that make them either acceptable or unacceptable for any given application. It is obviously important that the method which offers greatest advantages should be selected.

The grease-packed and oil-filled offer similar advantages and disadvantages. The main advantage is simplicity of operation. They are also economical, easy to maintain and the grease type resists the entry of contaminants. In addition, high tooth loading can be accommodated since lubricants with heavy bodied oil can be used. An important requisite for the oil-filled type is that the coupling must have an adequate static oil capacity to provide the required amount of oil to submerge the teeth when the coupling is in operation. The greatest disadvantage of these couplings is the possible loss of lubricants during operation due to defective flange gaskets, loose flange bolts, lubricant plugs and flaws in the coupling flanges and spacers. Additionally, the grease type coupling is subject to grease separation at high speeds. Therefore, the grease coupling is not considered suitable for high speed service except when approved high speed coupling grease is used, and then only for up to one year of continuous operation.

The importance of selecting the best grease for the high speed coupling cannot be over emphasized. Laboratory screening and field experience has been our method of selecting the most suitable grease for our application. The laboratory screening was done with a Sharples high speed laboratory centrifuge. The greases were tested by centrifuging for 2½ hours at 50,000 rpm (60,000 G). This time and speed was chosen because the speed limit

of our centrifuge was 60,000 G and separation had equalized in 2½ hours.

In order to further study the separation characteristics of greases, centrifuging was done at four speeds—10, 20, 35 and 50 thousand rpm representing G forces of 2,400, 9,400, 27,000 and 60,000 respectively. Six-hour runs were made at each speed after which the weight percent and viscosity of the oil separated and the weight percent of the soap phase was determined at each speed. Our findings from these tests were relative to the original screening tests—that is, the greases with low separation characteristics indicated by the 2½ hour runs at 50,000 rpm were low at all speeds and the greases with high separation characteristics at 50,000 rpm were also high at all speeds. Therefore, based on this limited testing we selected the greases for our high speed grease-packed couplings. Experience in the field has paralleled the laboratory findings.

The continuous oil flow method is primarily used in our high speed rotating machinery. This method provides the potential for maximum continuous periods of operation at highest operating speeds. The flow of oil also provides a cooling advantage by carrying away heat generated within the coupling. Another important advantage is maximum reliability since the oil supply is constant and the loss of oil from within the coupling is not a problem as it is with oil- or greased-filling couplings. The main requisites for this method are (1) provision of adequate oil flow *into* the coupling, (2) the oil must be absolutely clean and (3) it must cool in order to carry away heat.

Some of the disadvantages of the continuous oil flow type coupling are (1) increased cost, (2) requires supply oil and return oil piping and (3) the entry of foreign solids with the oil will cause accelerated wear.

Foreign material in the oil is a major problem with this type coupling. Since high centrifugal forces are developed within the coupling, any induced solids and water will be extracted from the oil and retained in the coupling. Abrasive wear is usually caused by the trapped sludge. In addition to the foreign abrasives, the sludge will retain the wear metal and will contribute to the coupling wear rate.

Sludging has been reduced within some of our couplings by improved filtration of the oil. The 5-micron elements in the console oil filters were replaced with ½-micron elements without creating an excessive pressure drop. The initial differential pressure with the new ½-micron elements was 5 psig. These elements were used in continuous service for six months until the train was shut down for inspection. The differential pressure across the filters at that time was less than 10 psig. We are also using separate duplex filters on the oil stream to a few couplings with success. These filters are equipped with differential pressure alarms.

The gear type coupling on turbomachinery can be successfully lubricated by both oil and grease methods. The grease-packed and oil-packed couplings must be absolutely oil and grease tight to prevent the loss of lubricant and the very best high speed coupling grease must be used. The continuous flow type must have

absolutely clean oil supplied continuously at the designed flow rate.

#### SUMMARY

An attempt has been made to present a general discussion on the fundamentals of Lubrication related to turbomachinery. Emphasis was placed on the importance of:

1. Properly designed oil systems.
2. Selection of the correct oil that meets the requirements of the machine builder and the environments.
3. Establishing a suitable oil sampling and testing program.
4. Providing adequate methods of contaminant removal, including particulates, water and process gases.
5. Establishing and following a good procedure for cleaning and flushing the oil system.
6. Selecting the best method of coupling lubrication and providing the necessary attention to eliminate premature failures due to the loss of lubricant from the grease-packed and oil-filled units and from sludging in the continuous oil flow couplings.